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*With the Compliments of the*

**Society of Gas Lighting.**

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# The Electric Light.

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Copy of a Paper read by Mr. Eugene Vanderpool, Engineer of the Newark Gas Light Company, before the Society of Gas Lighting, at their regular meeting Dec 12, 1878.

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For Distribution among its Members and Friends.

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# THE ELECTRIC LIGHT.

The production of the electric light, by causing pieces of carbon or charcoal to form part of an electric current, is no new thing; it was described, carefully and in detail, as early as the year 1819, in The Transactions of the Royal Society, by Mr. Noad.

This light was produced by the electric currents derived from a powerful battery. The light is now produced by means of the magneto-electric (or dynamo-electric) machines, "a term given to a collection of parts, or mechanism, intended to create and gather together induced currents." By these machines an electric current is induced by the rapid motion of certain parts, near each other, but not in contact. These machines are the outcome of the demonstration by Faraday, in 1830, that an electric current could be generated by a magnet moved inside of a bobbin surrounded by insulated wire.

The expense and the difficulty of the division of the electric current have hitherto prevented any very extended use of electricity as an illuminating agent. But of late years the vast amount of scientific research that has been devoted to electricity has resulted in the production of dynamo-electric machines that are, probably, as perfect as any machines, considered in their function of converting mechanical power into electricity. The feasibility of dividing the electric current, demonstrated by the experiments of M. Konn, of St. Petersburg, and of M. Jablochkoff, at Paris (although neither divide the current in the same manner that we divide a current of gas), and the adoption for trial of the latter's system in lighting certain of the prominent places of Paris, have caused those interested in gas lighting to investigate the merits of a system of illumination which some think may interfere somewhat with the field of gas lighting, and has caused others to prophesy that the days of the gas companies are numbered.

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There are two systems of electric lighting at present in use:

I. Where a single light of high intensity is supplied directly by a single dynamo-electric machine.

II. Where several lights of a lower intensity are supplied by a single dynamo-electric machine.

The former system, where the light alone is considered, is more economical than the latter.

M. Fontaine, in his work, "Éclairage à L'Éectricité," says:

"With equal first cost a lighting apparatus with a regulator therefore produces twelve times more light than one with a candle."

Again, as to the cost of the candle:

"An electric candle that lasts half an hour costs fifty centimes, which is equal to one franc per hour for forty Carcel burners (twenty cents for 384 candles), and ten francs fifty centimes per hour for 500 burners. Now the same amount of light is produced at M. Ménier's establishment, at Grenelle, with twenty-five centimes' worth of ordinary carbon pencils. The outlay for carbons is, therefore, fifty times greater by the use of the candle than by the use of the regulator."

The regulator lights are very intense, and their illuminating value, where intensity alone is considered, is very high. The works of Messrs. Sautter, Lemonnier & Co., the makers of the Gramme machine, are lighted by these concentrated lights, the carbons being regulated by means of the Serrin regulator or lamps.

They have in use six of these lamps, each said to give the light of 2,000 candles, or 12,000 candles in all. The electric current in these lamps always passes in the same direction. Each lamp requires three H. P., to develop the light. The expense and complication attending the use of a separate dynamo-electric machine for each burner, with the wires to and from each burner, irrespective of the value of the light, make it impracticable to use lights of this description but in exceptional localities, and it is not necessary, now, further to consider this system of electric lighting.

The second system is that in which the electric current is said to be divided, and a number of lights are maintained upon the same current. Say as in the Jablochkoff system—four or five lights upon the same wire, and current, from one dynamo-electric machine. This system is of more interest to us, as a method of this kind can alone affect the system of gas lighting. There are two methods at present before the public whereby the current of electricity is said to be divided and several lights produced by it:

I. Where the voltaic arc is produced, and an absolute combustion or oxidation of the carbon takes place, as in the Jablochkoff, Werdermann, and other systems. None of these admit of much breaking up of the current, none of them exceeding, up to the present, ten lights on a single current. And,

II. Where the light is produced by incandescence, as in the Edison, Sawyer & Mann, Konn, King, and other systems.

Of the first, the Jablochkoff system is that by far the most prominent, and, indeed, the only one that has been practically developed and tested. It is called the Jablochkoff system on account of the peculiar arrangement of the carbons called candles. These candles consist of two pieces of carbon in the shape of cylinders (prepared from pulverized coke or retort carbon, compressed and held together by a glue), three-sixteenths of an inch in diameter and eight and three-fourths inches long, distant from centre to centre five-sixteenths of an inch, and separated, except at the top, by a plate of plaster of Paris, or some other refractory material. At the top the two carbons are connected by means of fusible mixture of carbon of a smaller cross section than the two pieces of carbon forming the candle. At the bottom the two carbons are fastened into a socket, into which also the wires connect. The current passing through the two vertical carbons heats the fusible top, this communicates heat to the vertical carbons, the voltaic arc is produced between them, the refractory material is consumed by the heat, and the carbons are consumed by oxidation.

These candles burn, on an average, an hour and a-quarter each, at the end of which time it is necessary for an attendant to visit each lamp and change the current to another candle, of which there may be four or more in each globe. No automatic arrangement has been invented to overcome this difficulty and expense. To render this candle useful a modification has to be made in the ordinary dynamo-electric machine, as, when the voltaic arc is produced between two carbon points by means of a constant current of electricity, the positive carbon is consumed twice as fast as the negative. But by means of a magnetic machine, acting as a commutator, the current is made alternating. A commutator running at a speed of 800 revolutions per minute is said to cause a reversal of the polarity of the current amounting to some 64,000 times in a minute. It is said that the alternating of the current wastes or destroys a large amount of the current generated by the first machine. There are at present three forms of the Gramme dynamo-electric machines giving an alternating current, described by the Jablochkoff Lighting Company as follows:

The first size feeds sixteen Jablochkoff candles of 1,500 candle power each, requires sixteen H. P., and costs in Paris $2,000. Its maximum length is thirty-five inches, its width thirty inches, its height thirty-one inches. This machine makes 600 revolutions a minute, and weighs 1,430 pounds. The total weight of copper wire in action is 226 pounds. The second size feeds six Jablochkoff candles of 1,500 candle-power each, requires six H. P., to drive it, and costs $1,000. Its length is twenty-eight inches, width fourteen inches, height twenty inches. This machine makes 700 turns a minute, and weighs 616 pounds. The total weight of copper wire in action is eighty-eight pounds. The third size feeds four Jablochkoff candles of 1,500 candle-power each, requires four H. P., to drive it, and costs $700. Its length is twenty-two inches, its width sixteen inches, and its height twenty inches. This machine makes 800 turns a minute, and weighs 418 pounds. There are sixty-two pounds of copper wire in action.

The current of electricity is carried to the lamps by a cable of copper wires, insulated, and covered with rubber. The diameter of the wires is three-eighths of an inch. These cables are carried from the dynamo-electric machines into the street, where they are placed in earthenware tiles or pipes. They may be placed either in the street or under the sidewalk. In Paris, in the Avenue de l'Opéra, they are placed under the sidewalks. The cost of this cable is stated to be sixteen cents a foot; when laid, of course, the expense would be much greater. The current is then carried to the lamps, which are placed at a greater height than the ordinary gas lamps, upon posts about sixteen feet from the level of the sidewalk. The lanterns consist of globes of opaline glass (Verre Opale), sixteen inches in diameter, and half an inch thick. These are made in this way so as to render the lights less intense and more diffusive. Of course, this heavy opaline glass obstructs the rays of light, probably to the extent of fifty per cent.

The Jablochkoff system has been developed and used to a greater extent in the city of Paris than elsewhere, and nowhere else have I seen the electric light, by any of the various systems, produced as efficiently, steadily, and beautifully.

I examined the lights and their effect in the Avenue de l'Opéra (including the Place de l'Opéra and the Place du Théâtre Français), where there are sixty lights;
The Orangerie du Jardin des Tuileries, thirty-two lights;
Façade of the Palais du Corps Legislatif, six lights;
Hippodrome (including fourteen naked lights), thirty-two lights;
Salon of the Hôtel Continental, four lights;
Théâtre du Chatelet (lighted inside, except the foot-lights);
Grand Hôtel du Louvre (court), eight lights;
Arc de Triomphe de l'Étoile, eighteen lights.

It is claimed by those interested in the Société Générale d'Électricité, Procédés Jablochkoff, that they can produce a certain amount of light by their system cheaper than it can be done by gas.

The following estimate is taken from a prospectus of the Company, published June, 1878:

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If we take, for example, a light made by sixteen luminous points, the hourly expense would be itemized as follows:

### ESTIMATE.

| | |
|---|---|
| Expense of sixteen candles per hour | $1 60 |
| Coal for the boilers, at the rate of 18 H. P., at 5½ ℔s. per H. P., per hour, coal at $7 per ton | 31 |
| Oil and waste | 05 |
| Wages of stoker | 12 |
| | $2 08 |

Each candle gives a light equal (by their estimate) to 100 gas lights, or, sixteen electric candles equal

$$1{,}500 \times 16 = 24{,}000 \text{ candle-power.}$$

The same amount of light from gas burned in five-feet gas-burners, if the above estimate is correct, would be three or four times more costly.

I do not consider the above estimate correct, for the following reasons:

The H. P., required per lamp is stated to be one, but various estimates of the power required give from the lowest, one H. P., up to four. In the Orangerie of the Tuileries there are two engines (said to be of thirty-five H. P., each) and boilers to drive the six electrical machines that supply the thirty-two lamps there. The best results obtained in the experiments at the Franklin Institute upon the comparative efficiency of dynamo-electric machines show that with the best dynamo-electric machine one horse-power produces the light of 383 candles. Now, if we deduct from this light the effect of the opaline globes used with the Jablochkoff candles, we have the available light produced about 190 candles per lamp, and the loss from the use of the alternating current still to be deducted. From the information obtained, and what I saw, it would be safe to estimate that two horse-power would be required to generate the electrical current for each lamp.

The wages of the stoker, or engineer, with us would be twenty cents.

### REVISED ESTIMATE.

| | |
|---|---|
| Expense of candles | $1 60 |
| Coal, 2 H. P., 32 H. P., 160 ℔s., at rate of $5 per ton | 35 |
| Oil and waste | 05 |
| Wages of engineer | 20 |
| | $2 20 |

We come now to the consideration of the light produced, and I am fully satisfied, from many careful observations, that its power has been far over-estimated. For instance, the Avenue de l'Opéra, a street one hundred and eight feet wide between the buildings and fifty-eight feet wide between the curbstones, and 3,100 feet in length from the opera house to the Théâtre Français, including the Place de l'Opéra and the Place du Théâtre Français, is lighted by sixty electric lamps, that take the place of about 300 gas burners. The electric lamps are located as follows:

In the Avenue de l'Opéra, between the Place de l'Opéra and the Place du Théâtre Français, thirty-six lamps;

In the Place du Théâtre Français, fourteen lamps;

In front of the Opéra, six lamps;

In the Place de l'Opéra, four lamps.

One can judge better of the power and effect of the lights here, perhaps, than elsewhere, and can compare the effects of electric and gas illumination by going into the adjacent Rue de la Paix, lighted entirely by gas lamps, placed forty-five feet apart on each side of the street, and each lamp has three lanterns containing a single burner.

Each of the electric lamps is claimed by the Jablochkoff Company to give the light of one hundred gas burners, or 1,500 candle-power. As a matter of fact, one electric lamp replaces less than six ordinary gas burners. The street is lighted by the electric lamps until midnight, when the candles are extinguished and the gas is lighted. I think that ten gas burners, consuming five cubic feet of sixteen-candle gas per hour, properly distributed, or fifty cubic feet per hour, consumed in large Argand burners in the electric lanterns, covered with clear glass shades, would light the avenue fully as well, if not better, than one of the electric lamps. I estimated the amount of light utilized from each electric lamp in the Avenue de l'Opéra at one hundred and sixty candles.

So that the light from sixteen Jablochkoff candles would be

$16 \times 160 = 2{,}560$ candles, which is equal to

$\frac{2560}{16} = 160$ gas burners, or $160 \times 5 = 800$ cubic feet of gas.

So that we have a light equal to 2,560 candles produced by electricity, costing $2.20, which is equal to $\frac{220}{800} = \$2.75$ per thousand, and there is nothing added for interest on capital (much larger with the electric than with the gas system of lighting), nor for the items of depreciation, taxes, cost of distribution, &c. In the Avenue de l'Opéra each electric lamp costs the city twenty-five cents per hour, and every ten gas burners four cents per hour, so that the city is paying six times as much for the same amount of light from electricity as it does for gas.

At these prices it is estimated the electrical company do not cover their expenses; and it is certain the city of Paris will not much longer indulge in what was said to be part of the Exposition, but which no longer attracts strangers. Recent advices state that the electric lamps are extinguished, except in the Avenue de l'Opéra, and that they are to be removed from the avenue on January 1st. This is confirmatory of what I was informed by excellent authority when in Paris.

The court of the Hôtel du Louvre is lighted by eight electric candles, that take the place of forty-eight gas burners. A fair estimate of the cost of the electric lighting, including the candles, coal for fuel of the ten horse-power engine, labor, interest and management, is, for one-quarter day, $8.37, which is at the rate of $\frac{837}{1440} = \$5.81$ per thousand cubic feet for the gas. There is more light given out by the electric lamps than by the gas, but a portion of the light is wasted. But assuming there is no loss, it would require eighty gas burners to give out the same amount of light, and the cost, per thousand, to equal the cost of the electric lighting would be $\frac{837}{2400} = \$3.48$. But the light is used here regardless of expense, as the Hotel and Magazin du Louvre are owned by the same parties, and in Paris, as elsewhere, the value of advertising is understood, and it is believed the light is used here simply for the purpose of a show.

Nearly all the questions connected with the generation and distribution of the electric light are at present unanswered to one desirous to investigate them for the benefit of science or capital. The questions of the power required, the light produced, the expense of engines and boilers, the distributing wires, the wear and tear, &c., &c., are none of them satisfactorily determined. It is doubtful whether these questions will be reliably determined until the gas companies, as I think they should do, employ the highest scientific and mechanical talent, and test all of these matters independently. There are some points connected with the electrical light that seem evident to one accustomed to measure and estimate the values of various lights and systems of lighting. One important point is that the illuminating power, or rather the illuminating value, of the electric light is far over-estimated. This fact has been observed and commented upon by not a few; among others, by the well-known photometric experts, Messrs. Wm. Sugg and F. W. Hartley.

It seems to be a fact that measurements of the light produced by electricity, as determined by the photometer, are very incorrect, and that the photometer, as ordinarily constructed and used, does not indicate accurately the comparative value of two lights varying in intensity and quantity to so great a degree as do those produced by gas and electricity. This fact, with others bearing upon the question of illumination, was intimated nearly thirty years ago, by Mr. Lewis Thompson. In an article on the

PHOTOMETRICAL CHARACTERISTICS OF FLAME,

he says: "By quantity of light, we mean that the luminiferous particles are then numerous; by intensity, that the temperature to which they are heated is very high.

"These peculiarities of flame are very well marked, and easily distinguished, and the perfection of burning coal gas seems to reside in a happy admixture of the two conditions, though it is obvious that of these states the peculiarity called quantity is preferable to intensity. To distinguish between these conditions, we may remark that the quantity of light depends upon the number of carbonaceous particles actually heated in a given time; whereas intensity of light has reference only to the temperature to which these particles are heated. Thus, a great quantity of light may exist, but of low intensity. And again, great intensity is sometimes produced, though the quantity be but trifling. IT IS INTENSITY WHICH ACTS CHIEFLY UPON THE PHOTOMETER, BUT THE HUMAN EYE RECOGNIZES QUANTITY ALSO.

"Thus, if we heat an inch of platinum wire red hot, it will give off a certain quantity and intensity of light; and if we heat two inches red hot, we shall only double the quantity, the intensity remaining as before; whereas, if we heat these two inches to a white heat, the intensity will be much increased, though the quantity remains the same. Conversely, by increasing the heat the intensity may be increased, though the quantity remains unaltered; and in this case there is a remarkably bright light, with no less remarkable dark shadows. As an example of 'intensity' the electric light and the oxy-hydrogen lime light are good illustrations; for the number of particles actually in operation at any one moment is very small, whilst the temperature to which they are exposed is the greatest we can produce, and, therefore, a painfully glaring light results, with very dark shadows. In opposition to this, we have the common oil lamp, or lamp of the ancients, with its thick wick and conical flame, affording a great 'quantity' of light, but of a very low 'intensity;' and the Argand oil lamp, in which, by turning the back to the flame, and regarding steadily the walls of the apartment, whilst an assistant obstructs the supply of air to the flame, it is found the walls become *more* illuminated, though the flame itself looks yellow and smoky; whilst, by restoring the supply of air, the flame becomes bright, and the walls less distinctly visible than before. There cannot be a greater error, therefore, in the construction of gas burners than that which converts quantity of light into intensity, by consuming one portion of the solid carbon that another may be more intensely heated."

## Plant Required for the Production of the Electric Light.

One cannot but be struck with the enormous outlay, in the shape of boilers, engines, dynamo-electric machines, &c., that would be required in case an attempt was made to introduce the Jablochkoff system of electric lighting on a large scale.

It would appear that the item of interest on the capital required would be alone fatal to its adoption, even if the system was a practical one.

For instance, an electric lighting company is required to make and supply the light of 400,000 candles in a single hour, which hour would be the one of the maximum consumption of the year. To produce this light by electricity it would require, allowing 150 candles per horse power, $\frac{400,000}{150}=2,666$ horse power. Inasmuch as the electric current cannot be stored, or has not been so far, and as the lights go out the instant the engine stops, it would seem imperative to have, for safety, all of the generating apparatus in duplicate, so that we would have to provide 5,332 horse power in engines, dynamo-electric machines, buildings, real estate, &c., and this broken up into small stations, some of which must be located in the best part of the cities to be supplied, as it is found from experience that the electric current of the dynamo-electric machines cannot be carried more than two hundred yards from the station without greatly increased expense and difficulty.

M. Jablochkoff makes an estimate to supply in Paris a six-horse power engine, boiler, lanterns, dynamo-electric engine, and four burners, for the sum of $2,325, being at the rate of $581.25 per lamp. If we add to this the cost of a suitable building, real estate, &c., it would make the cost per lamp and for horse power much greater.

Mr. G. H. Stayton, C. E., Surveyor to the Vestry of Chelsea, in his report to the Vestry, July 30th, 1878, estimated that to light Sloane street would require two electric stations, each of which would require a sixteen-horse power engine, boilers, dynamo-electric machines, building, conductors, &c., and that the cost would be $16,000. There is no real estate included. This makes the cost per horse power $500. It would not be out of

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the way to estimate $500 as the cost for the productive plant per horse power. This makes an expenditure of 5,332 X 500=$2,666,000 in productive plant alone, or far in excess of the amount required for gas.

## Effect of the Outlay in Producing Plant Upon the Cost of the Light.

Now, if 400,000 candles per hour, maximum consumption, represents a yearly gas consumption of 200,000,000 cubic feet; the interest account on producing plant for the electric light would be, at ten per cent., $266,600, and the charge per thousand, to meet it, $\frac{266,600}{200,000,000}=\$1.33$.

If we now add to the electric light the cost of production, depreciation, distribution, taxes, royalty, interest on distributing plant, it is evident that it is impossible to sell the electric light produced by the Jablochkoff system in competition with gas sold by a well-managed and fairly capitalized gas company.

## General Effect of the Electric Light in the City of Paris.

The electric light in Paris, whether used in the streets, theatres, court-yards, or salons, was nowhere satisfactory. It had no diffusive properties, it varied continuously in its intensity and color, it was injurious to the eyes, and unbecoming to the complexion. The light, to use an unscientific term, did not travel well. To one standing near the Arc de l'Étoile, and looking at the electric lamps surrounding it, there seemed to be a great deal of brightness, and the intermediate gas lamps looked quite overcome and dimmed by the dazzling lustre of their rivals. These lamps were supposed to be giving out a greater amount of light than those in the Avenue de l'Opéra, and cost the city thirty-five cents per hour each, or ten cents an hour more than the latter, the hope being that by their use the façade of the arc would be brilliantly lighted; but the experiment in this respect was not successful. When one reached the Place de la Concorde, one and a-third miles away, and looked up at the arc, it was hard to distinguish the electric from the gas lamps.

## DEFECTIVE CHARACTER OF INTENSE LIGHTS.

Such large and intense lights, except where lights of this character are needed, are wasteful of the light, because the power of light decreases as we recede from the point of production, as the square of the distance.

So that if we get a certain amount of light at a distance of one foot from the centre of the light, and at a distance of twenty feet we get but one four-hundredth, and at the distance of twenty feet we get all of the light required, it is evident that at the distance of one foot and up to nineteen feet the illumination is greater than needed, and is, practically, wasted. Of course, the greater the intensity of the light, the greater is the comparative loss. Then there is the defect of all intense lights to be considered that the shadows produced are so painfully marked and defined. It seems that Lavoisier was correct, when, in his prize paper before the Academy of Sciences, in 1766, upon the best manner of lighting streets and halls, he stated that to obtain a proper illumination it was necessary to employ a large number of luminous sources, with a large lighting surface, but of a feeble intensity.

## DIFFICULTIES CONNECTED WITH THE JABLOCHKOFF SYSTEM.

There are many difficulties connected with the distribution of the light by the Jablochkoff system, it becoming complicated in proportion to the number of lights, four lights being found the limit to be produced on a single current on the same wire; this means a wire to every two burners in use, running from the dynamo-electric machine. One serious drawback is the fact that if one of the burners of the four in the same circuit goes out they all go out, and cannot be relighted without difficulty and a great loss of time. The system requires competent and constant supervision. In simplicity, convenience and divisibility there is hardly a comparison between the Jablochkoff system and gas lighting favorable to the former. I think the gas companies have nothing to fear in the Jablochkoff system as developed up to the present time.

## THE INCANDESCENT SYSTEM OF ELECTRIC LIGHTING.

When, instead of obtaining the electric light by means of the voltaic arc, it is obtained from a substance that by its resistance to the electric current becomes highly heated, or incandescent, we have the system in use by Mr. Edison, Sawyer & Mann, Konn, and others.

Of these systems that of Mr. Edison is, perhaps, creating the most interest at the present.

Mr. Edison states that his desire is to produce at a distance of half a mile from the electric station lights equal to fifteen candles, that, burning ten hours per diem for three hundred and sixty-five days in the year, will cost $1.95 each.

He states that he has obtained, up to the present, the light of forty-five candles, or three burners of fifteen-candle power each, per H. P., by means of the dynamo-electric machines in use; but he hopes, and is confident, that, with improved dynamo-electric machines, he can produce the light of ninety candles, or six burners of fifteen candles each, per H. P.

He hopes, with an eighty H. P. engine of the most approved construction, consuming at the rate of two pounds of fuel per hour per H. P., to produce four hundred and eighty burners, giving the light of fifteen candles each, that will cost $1.95 each per annum. Mr. Edison estimates the cost of each gas burner to be $15 per annum.

Mr. Edison does away entirely with carbon, and produces his light by keeping up to a temperature of 3,400 degrees F. a solid substance. The question might be asked here, how long a substance which daily might be heated from 60 degrees to 3,400 degrees, and must expand and contract, would last.

Mr. Edison says he can maintain one, ten, ten thousand, or one hundred thousand burners on the same circuit; the division is practically unlimited. The extinction of one light, ten, or twenty, or those of a whole building, will not affect the intensity or the working of the others. Each light is independent and takes care of itself. He can now measure the quantity consumed. He estimates the capital required for an electric lighting company to be three times that required by a gas company. He can supply a district, say from Chambers street, New York, to the Battery, and from the East to the North river, from one station. He would require from fifteen to twenty stations to supply the city of New York.

Mr. Edison thinks the cost of distribution, salaries, office hire, &c., would be as large with his system as with gas.

We can make an estimate on Mr. Edison's burners, and see if, with the data given by him, and what can be obtained elsewhere, it is probable that his figures are correct.

The cost per H. P., for engine, boilers, dynamo-electric machines, shafting, building, real estate in choice parts of the city, would be low at $500.

Two pounds of fuel, per hour, per H. P., would be very low in average work, but we will assume this as correct. This would be 1,401,600 pounds per annum.

The engineers to run this engine would have to be of a superior grade, and would cost not less than $2.50 each per diem.

The depreciation, or wear and tear on the machinery producing the electric light, would average ten per cent., or more.

## ESTIMATE OF THE COST OF LIGHTING 480 ELECTRIC BURNERS WITH AN 80 H. P., ENGINE FOR ONE YEAR.

We will divide the estimate into three parts:

### I.—COST OF COAL AND LABOR.

| | |
|---|---|
| 1,401,600 lbs. of coal, $4.50 per ton................ | $2,803 20 |
| Wages of two engineers, @ $2.50.................. | 1,825 00 |
| " " stokers, @ $1.50.................... | 1,095 00 |
| Total.................................. | $5,723 20 |

Making, for these items, cost per burner per annum, $11.92.

*Note.*—If we estimate the consumption of fuel at five pounds per H. P., per hour, and there are very few engines that do not require more, the cost would be increased by the sum of $4,204.80, making the cost per burner per annum $20.68.

### II.—COST OF DEPRECIATION, WEAR AND TEAR.

It is estimated that not less than ten per cent., would be required to cover the annual depreciation in the boilers, engines, dynamo-electric machines, shafting, &c., employed to produce the electric light; and if seventy-five per cent. of the capital would be required for the machinery, the annual charge would be $30,000 at ten per cent., $3,000.

Making, for these items, the cost per burner per annum, $6.25.

### III.—Cost for Interest on Capital.

We will assume the capital to be loaned, and bearing interest at the rate of six per cent per annum, although it would be fair to think that the stockholders in an electric light company would be as grasping as those of a gas company in endeavoring to realize ten per cent. on their capital. Interest on $40,000 at six per cent., $2,400.

Making, for this item, the cost per burner per annum, $5.

Therefore, we have the following as the cost of each burner per annum:

| | |
|---|---|
| I.—Coal and labor | $11 92 |
| II.—Depreciation, wear and tear | 6 25 |
| III.—Interest on loaned capital | 5 00 |
| Total | $23 17 |

So that we have, as the cost of each burner per annum, $23.17, or about twelve times the amount estimated by Mr. Edison.

If we take the fuel at five pounds per H. P., per hour, and the interest on capital at ten per cent., the cost per burner per annum would be $35.25. Besides there are the items of superintendence, taxation, office hire, distribution, interest on distributing plant, salaries, &c., to be added.

It is hard to see how Mr. Edison, in making an estimate to supply a certain district with the electric light, say a certain block, could do otherwise than take the number of gas burners at present in use, and estimate for the plant adequate to supply any and all of these burners at any and all times. The electric system of distribution does not admit of the sure and automatic increase of supply to meet the demand that obtains with gas.

In Philadelphia there are in use, as per Annual Report of the

Trustees of the Philadelphia Gas Works, for 1877, 1,361,836 lights, by 93,759 consumers, or 14.5 burners, on the average, for each consumer. The cost of the producing plant for each electric burner is $\frac{500}{6}$=\$83.33 ; the cost of producing plant for each consumer, on the average, would be \$83.33 × 14.5=\$1,208.28, and the interest on this, at six per cent., would be \$72.49. The gas consumed by each one of these gas burners was $\frac{1,362,130,300}{1,361,836}$=1,000 cubic feet, and the quantity burned by each consumer was $\frac{1,362,130,300}{93,759}$=14,500 cubic feet. This, at \$2.50 per thousand, the price of gas in New York city, would be \$36.25 ; or, the entire cost of gas, including interest on capital, to the consumer, on the average, would be but one-half the cost of interest on the producing plant alone for Mr. Edison's system. It is well to note that the average cost of each gas burner per annum is but \$2.50, instead of \$15. It is difficult to see how the above estimates for the electric light can be sufficiently modified to make it a competitor with gas selling even at a higher price than \$2.50 per thousand; and we are far from believing that with better times, increased attention and economy, gas cannot be sold at a profit a good deal below \$2.50 per thousand.

If high scientific authority is to be credited, lighting by incandescence cannot possibly compete with gas lighting.

Prof. S. P. Thompson, of the University College, Bristol, in a letter to the editor of "Engineering," dated November 22, 1878, says:

"In no existing case is lighting by incandescence economical. Certainly it will not be when subdivision is carried out. And no electric light has yet been devised that lends itself to subdivision as readily as the uneconomical light produced by the incandescence of a solid conductor. What we want is a cheaper source of electricity, so that we can afford to waste as much as we please in subdivision, and in the wasteful production of small lights. But that cheaper source of electricity is not yet discovered."

### Future of the Electric Light.

It would be excessively bold, and would show a disregard for the past achievements of science, to say that there is no Future for the electric light; but as developed at present, there is no reason in the alarm at present existing among those interested in gas property. I have spoken of the dynamo-electric machine as a very perfect machine. The most economical boilers and engines give, in work, less than ten per cent. of the energy produced by the combustion of the fuel. It is a good engine that utilizes five per cent. of the energy of the fuel. Reliable experiments show that the dynamo-electric machines built by Siemens utilize seventy per cent. of the energy imparted to them; so that it is evident there can be but little improvement in the machines themselves, as far as the expenditure of power, and, consequently, fuel in running them, is concerned. Experiments made in 1865 show that the theoretical equivalent of the energy of one H. P. is represented by 3,000 candle-power; so that the best possible work that can be done by a dynamo-electric machine is 3,000 candles per H. P. Of course this limit can never be reached in practice, on account of the dissipation of energy that must take place in every machine.

Again, there are certain laws laid down by electricians with reference to the production, distribution and division of electrical currents, which, if true, seem to be fatal to the use of electric lighting for domestic purposes.

One of these laws is that the heat, or light, produced by an electric current varies as the square of the strength of the current. Consequently, if a current of a certain intensity produces a light equal to 1,000 candles, and we break it up into ten currents, instead of getting ten lights of one hundred candles each, we get but

$\frac{1000}{10^2}=10$; or, there is a loss in illuminating power as follows:

| | | |
|---|---|---|
| Original light.................................. | 1,000 | candles. |
| Ten lights of ten candles each................... | 100 | “ |
| Loss.......................................... | 900 | “ |

Per centage of loss, ninety.

It must be an excessively cheap light that can stand a leakage of ninety per cent. Mr. Edison says he has discovered a law compensatory of this, so that he meets with no loss by his subdivision; and yet his figures show that if he is as successful as he hopes to be, he will obtain but one-tenth the light per H. P., obtained by other systems.

Experiments hitherto made indicate that for general uses, with the present methods of producing and distributing electricity, and with the present cost for plant, lighting by electricity must be more complicated and expensive than by gas, and that there is little probability of the income of the gas companies being diminished by competition with the electric light.

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